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(60) Parent Application or Grant BAKER HUGHES INCORPORATED [/]; O. ARONSTAM, Peter, S. [/]; O. BERGER, Per-Erik [/]; O. RIDDLE, J., Albert ; O.	

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- (54) Title: METHOD OF UTILIZING FLOWABLE DEVICES IN WELLBORES
(54) Titre: PROCEDE D'UTILISATION DE DISPOSITIFS FLUIDES DANS DES FORAGES

(57) Abstract

This invention relates to flowable devices and methods of utilizing such flowable devices in wellbores to provide communicate between surface and downhole instruments, among downhole devices, establish a communication network in the wellbore, act as sensors, and act as power transfer devices. The flowable devices are adapted to move with a fluid flowing in the wellbore. The flowable device may be memory device or a device that can provide a measure of a parameter of interest or act as a power transfer device. The flowable devices are introduced into the flow of a fluid flowing in the wellbore. The fluid moves the device in the wellbore. If the device is a data exchange device, it may be channeled in a manner that enables a device in the wellbore to interact with the memory device, which may include retrieving information from the flowable device and/or recording information on the flowable device. The sensor in a flowable device can take a variety of measurement(s) in the wellbore. The flowable devices return to the surface with the returning fluid.

(57) Abrégé

La présente invention concerne des dispositifs fluides et des procédés d'utilisation de ces dispositifs fluides dans des forages pour établir une communication entre la surface et des instruments de fond; entre les appareils de fond; établir un réseau de communication dans le forage; agir comme des capteurs; et agir comme des dispositifs de transfert de puissance. Les dispositifs fluides sont conçus pour se déplacer avec un fluide s'écoulant dans le forage. Le dispositif fluide peut être un dispositif à mémoire ou un dispositif capable de mesurer un paramètre intéressant ou d'agir comme un dispositif de transfert de puissance. Les dispositifs fluides sont introduits dans le flux d'un fluide s'écoulant dans le forage. Le fluide déplace le dispositif dans le forage. Si le dispositif est un dispositif d'échange de données, on peut répartir ses voies pour permettre à un dispositif se trouvant dans le forage d'entrer en interaction avec le dispositif à mémoire, ce qui peut consister à extraire des informations du dispositif fluide et/ou à enregistrer des informations dans le dispositif fluide. Le capteur dans un dispositif fluide peut prélever différentes mesures dans le forage. Les dispositifs fluides remontent à la surface avec le fluide de retour.

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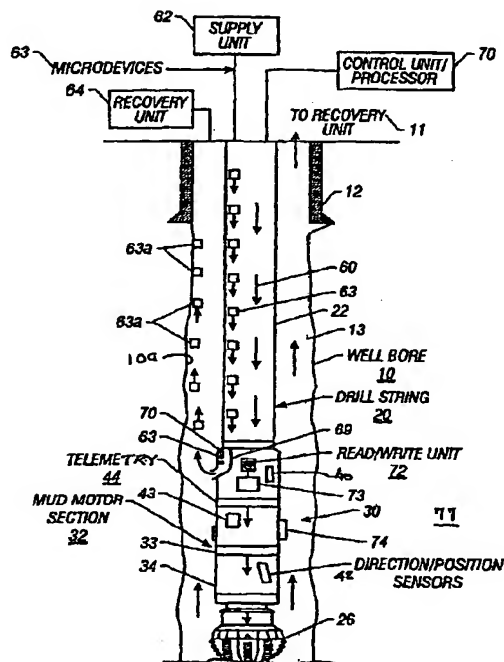
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- (71) Applicant: BAKER HUGHES INCORPORATED
[US/US]; Suite 1200, 3900 Essex Lane, Houston, TX 77027 (US).
- (72) Inventors: ARONSTAM, Peter, S.; 10727 Cedar Creek Drive, Houston, TX 77042 (US). BERGER, Per-Erik; Hegreberg, N-4152 Vestre Amoy (NO).
- (74) Agents: RIDDLE, J., Albert et al.; Baker Hughes Incorporated, Suite 1200, 3900 Essex Lane, Houston, TX 77040 (US).
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(54) Title: METHOD OF UTILIZING FLOWABLE DEVICES IN WELLBORES



(57) Abstract: This invention relates to flowable devices and methods of utilizing such flowable devices in wellbores to provide communicate between surface and downhole instruments, among downhole devices, establish a communication network in the wellbore, act as sensors, and act as power transfer devices. The flowable devices are adapted to move with a fluid flowing in the wellbore. The flowable device may be memory device or a device that can provide a measure of a parameter of interest or act as a power transfer device. The flowable devices are introduced into the flow of a fluid flowing in the wellbore. The fluid moves the device in the wellbore. If the device is a data exchange device, it may be channeled in a manner that enables a device in the wellbore to interact with the memory device, which may include retrieving information from the flowable device and/or recording information on the flowable device. The sensor in a flowable device can take a variety of measurement(s) in the wellbore. The flowable devices return to the surface with the returning fluid.

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Description

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METHOD OF UTILIZING FLOWABLE DEVICES IN WELLBORES

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application takes priority from United States Patent Application Serial Nos. 60/136,656 filed August 5, 1999, and 60/147,127 filed May 28, 1999, each assigned to the assignee of this application.

BACKGROUND OF THE INVENTION**1. Field of the Invention**

This invention relates generally to oilfield wellbores and more particularly to wellbore systems and methods for the use of flowable devices in such wellbores.

2. Background of the Art

Hydrocarbons, such as oil and gas, are trapped in subsurface formations. Hydrocarbon-bearing formations are usually referred to as the producing zones or oil and gas reservoirs or "reservoirs." To obtain hydrocarbons from such formations, wellbores or boreholes are drilled from a surface location or "well site" on land or offshore into one or more such reservoirs. A wellbore is usually formed by drilling a borehole of a desired diameter or size by a drill bit conveyed from a rig at the well site. The drill string includes a hollow tubing attached to a drilling assembly at its bottom end. The drilling assembly (also referred to herein as the "bottomhole assembly" or "BHA") includes the drill bit for drilling the wellbore and a number of sensors for determining a variety of subsurface or downhole parameters. The tubing usually is a continuous pipe made by joining relatively small sections (each

5 section being 30-40 feet long) of rigid metallic pipe (commonly referred to as the
"drill pipe") or a relatively flexible but continuous tubing on a reel (commonly referred
10 to as the "coiled-tubing"). When coiled tubing is used, the drill bit is rotated by a
drilling motor in the drilling assembly. Mud motors are most commonly utilized as
5 drilling motors. When a drill pipe is used as the tubing, the drill bit is rotated by
rotating the drill pipe at the surface and/or by the mud motor. During drilling of a
15 wellbore, drilling fluid (commonly referred to as the "mud") is supplied under
pressure from a source thereof at the surface through the drilling tubing. The mud
20 passes through the drilling assembly, rotates the drilling motor, if used, and
discharges at the drill bit bottom. The mud discharged at the drill bit bottom returns
10 to the surface via the spacing between the drill string and the wellbore (also referred
25 herein as the "annulus") carrying the rock pieces (referred to in the art as the
"cuttings") therewith.

30
15 Most of the currently utilized drilling assemblies include a variety of devices
and sensors to monitor and control the drilling process and to obtain valuable
35 information about the rock, wellbore conditions, and the matrix surrounding the
drilling assembly. The devices and sensors used in a particular drilling assembly
depend upon the specific requirements of the well being drilled. Such devices
40 20 include mud motors, adjustable stabilizers to provide lateral stability to the drilling
assembly, adjustable bends, adjustable force application devices to maintain and
45 to alter the drilling direction, and thrusters to apply desired amount of force on the

5 drill bit. The drilling assembly may include sensors for determining (a) drilling
parameters, such as the fluid flow rate, rotational speed (r.p.m.) of the drill bit and/or
10 mud motor, the weight on bit ("WOB"), and torque of the bit; (b) borehole
parameters, such as temperature, pressure, hole size and shape, and chemical and
5 physical properties of the circulating fluid, inclination, azimuth, etc.; (c) drilling
assembly parameters, such as differential pressure across the mud motor or BHA,
15 vibration, bending, stick-slip, whirl; and (d) formation parameters, such as formation
resistivity, dielectric constant, porosity, density, permeability, acoustic velocity,
20 natural gamma ray, formation pressure, fluid mobility, fluid composition, and
10 composition of the rock matrix.

25 During drilling, there is ongoing need to adjust the various devices in the drill
string. Frequently, signals and data are transmitted from surface control units to the
drilling assembly. Data and the sensor results from the drilling assembly are
30 communicated to the surface. Commonly utilized telemetry systems, such as mud
15 pulse telemetry and acoustic telemetry systems, are relatively low data rate transfer
systems. Consequently, large amounts of downhole measured and computed
35 information about the various above-noted parameters is stored in memory in the
drilling assembly for later use. Also, relatively few instructions and data can be
40 transmitted from the surface to the drilling assembly during the drilling operations.
20

5 After the well has been drilled, the well may be completed, i.e., made ready
for production. The completion of the wellbore requires a variety of operations, such
10 as setting a casing, cementing, setting packers, operating flow control devices, and
perforating. There is need to send signals and data from the surface during such
5 completion operations and to receive information about certain downhole
parameters. This information may be required to monitor status and/or for the
15 operation of devices in the wellbore ("downhole devices"), to actuate devices to
perform a task or operation or to gather data about the subsurface wellbore
completion system, information about produced or injected fluids or information
20 about surrounding formation. After the well has started to produce, there is a
continuous need to take measurements of various downhole parameters and to
25 transmit downhole generated signals and data to the surface and to receive
downhole information transmitted from the surface.

30 The present invention provides systems and methods wherein discrete
15 flowable devices are utilized to communicate surface-generated information (signals
and data) to downhole devices, measure and record downhole parameters of
35 interest, and retrieve from downhole devices, and to make measurements relating
to one or more parameters of interest relating to the wellbore systems.

SUMMARY OF THE INVENTION

This invention provides a method of utilizing flowable devices to communicate between surface and downhole instruments and to measure downhole parameters of interest. In one method, one or more flowable devices are introduced into fluid flowing in the wellbore. The flowable device is a data carrier, which may be a memory device, a measurement device that can make one or more measurements of a parameter of interest, such as temperature, pressure and flow rate, and a device with a chemical or biological base that provides some useful information about a downhole parameter or a device that can transfer power to another device.

In one aspect of the invention, memory-type flowable devices are sent downhole wherein a device in the wellbore reads stored information from the flowable devices and/or writes information on the flowable device. If the flowable device is a measurement device, it takes the measurement, such as temperature, pressure, flow rate, etc., at one or more locations in the wellbore. The flowable devices flow back to the surface with the fluid, where they are retrieved. The data in the flowable devices and/or the measurement information obtained by the flowable devices is retrieved for use and analysis.

During drilling of a wellbore, the flowable devices may be introduced into the drilling fluid pumped into the drill string. A data exchange device in the drill string

5 reads information from the flowable devices and/or writes information on the
flowable devices. An inductive coupling device may be utilized for reading
10 information from or writing information on the flowable devices. A downhole
controller controls the information flow between the flowable device and other
5 downhole devices and sensors. The flowable devices return to the surface with the
circulating drilling fluid and are retrieved. Each flowable device may be assigned
15 an address for identification. Redundant devices may be utilized.

20 In a production well, the flowable devices may be pumped downhole via a
10 tubing that runs from a surface location to a desired depth in the wellbore and then
returns to the surface. A U-shaped tubing may be utilized for this purpose. The
25 flowable devices may also be carried downhole via a single tubing or stored in a
container or magazine located or placed at a suitable location downhole, from which
30 location the flowable devices are released into the flow of the produced fluid, which
15 carries the flowable devices to the surface. The release or disposal from the
magazine may be done periodically, upon command, or upon the occurrence of one
35 or more events. The magazine may be recharged by intervention into the wellbore.
The tubing that carries the flowable devices may be specifically made to convey the
40 flowable devices or it may be a hydraulic line with additional functionality. The
20 flowable devices may retrieve information from downhole devices and/or make
measurements along the wellbore. A plurality of flowable devices may be present
45 in a wellbore at any given time, some of which may be designed to communicate

5 with other flowable device or other downhole device, thereby providing a
communication network in the wellbore. The flowable devices may be intentionally
10 implanted in the wellbore wall to form a communication link or network in the
wellbore. A device in the wellbore reads the information carried by the flowable
5 devices and provides such information to a downhole controller for use. The
15 information sent downhole may contain commands for the downhole controller to
perform a particular operation, such as operating a device. The downhole controller
may also send information back to the surface by writing information on the flowable
20 devices. This may be information from a downhole system or confirmation of the
10 receipt of the information from surface.

25 Examples of the more important features of the invention have been
summarized rather broadly in order that the detailed description thereof that follows
30 may be better understood, and in order that the contributions to the art maybe
15 appreciated. There are, of course, additional features of the invention that will be
described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

35 For a detailed understanding of the present invention, reference should be
40 20 made to the following detailed description of the preferred embodiment, taken in

5 conjunction with the accompanying drawings, in which like elements have been
given like numerals, wherein:

10 **Figure 1** is a schematic illustration of a drill string in a wellbore during drilling
5 of a wellbore, wherein flowable devices are pumped downhole with the drilling fluid.

15 **Figure 2** is a schematic illustration of a wellbore during drilling wherein
flowable devices are implanted in the borehole wall to form a communications line
20 in the open hole section and wherein a cable is used for communication in the
10 cased hole section.

25 **Figure 3** is a schematic illustration of a wellbore wherein flowable devices
are pumped downhole and retrieved to the surface via a U-shaped hydraulic or fluid
30 line disposed in the wellbore.

15 **Figure 4** is a schematic illustration of a production well wherein flowable
35 devices are released in the flow of the produced fluid at a suitable location.

40 **Figure 5** is a schematic illustration of a multi-lateral production wellbore
20 wherein flowable devices are pumped down through a hydraulic line and released
into the fluid flow of the first lateral and where information is communicated from the

5 first lateral to the second lateral through the earth formation and wherein flowable
devices may also be released into the fluid flow of the second lateral to carry such
10 devices to the surface.

5 Figure 6 is a block functional diagram of a flowable device according to one
embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

20 The present invention utilizes "flowable devices" in wellbores to perform one
10 or more functions downhole. For the purpose of this disclosure, a flowable device
means a discrete device which is adapted to be moved at least in part, by a fluid
25 flowing in the wellbore. The flowable device according to this invention is preferably
of relatively small size (generally in the few millimeters to a centimeter range in
outer dimensions) that can perform a useful function in the wellbore. Such a device
30 15 may make measurements downhole, sense a downhole parameter, exchange data
with a downhole device, store information therein, and/or store power. The flowable
device may communicate data and signals with other flowable devices and/or
35 devices placed in the wellbore ("downhole devices"). The flowable device may be
programmed or coded with desired information. An important feature of the
40 20 flowable devices of the present invention is that they are sufficiently small in size so
that they can circulate with the drilling fluid without impairing the drilling operations.
Such devices preferably can flow with a variety of fluids in the wellbore. In another

5 aspect of the invention, the devices may be installed in the wellbore wall either permanently or temporarily to form a network of devices for providing selected measurement of one or more downhole parameters. The various aspects of the present invention are described below in reference to Figures 1-6 utilizing exemplary wellbores.

10 In a preferred embodiment, the flowable device may include a sensor for providing measurements relating to one or more parameters of interest, a memory for storing data and/or instructions, an antenna for transmitting and/or receiving signals from other devices and/or flowable devices in the wellbore and a control circuit or controller for processing, at least in part, sensor measurements and for controlling the transmission of data from the device, and for processing data received from the device. The device may include a battery for supplying power to its various components. The device may also include a power generation device due to the turbulence in the wellbore fluid flow. The generated power may be utilized to charge the battery in the device.

35 Figure 1 is an illustration of the use of flowable devices during drilling of a wellbore, which shows a wellbore 10 being drilled by a drill string 20 from a surface location 11. A casing 12 is placed at an upper section of the wellbore 10 to prevent collapsing of the wellbore 10 near the surface 11. The drilling string 20 includes a tubing 22, which may be a drill pipe made from joining smaller sections of rigid pipe

5 or a coiled tubing, and a drilling assembly 30 (also referred to as a bottom hole assembly or "BHA") attached to the bottom end 24 of the tubing 22.

10 The drilling assembly 30 carries a drill bit 26, which is rotated to disintegrate
5 the rock formation. Any suitable drilling assembly may be utilized for the purpose
15 of this invention. Commonly used drilling assemblies include a variety of devices
and sensors. The drilling assembly 30 is shown to include a mud motor section 32
that includes a power section 33 and a bearing assembly section 34. To drill the
20 wellbore 10, drilling fluid 60 from a source 62 is supplied under pressure to the
10 tubing 22. The drilling fluid 60 causes the mud motor 32 to rotate, which rotates the
25 drill bit 26. The bearing assembly section 34 includes bearings to provide lateral and
axial stability to a drill shaft (not shown) that couples the power section 33 of the
mud motor 32 to the drill bit 26. The drilling assembly 30 contains a plurality of
30 direction and position sensor 42 for determining the position (x, y and z coordinates)
15 with respect to a known point and inclination of the drilling assembly 30 during
drilling of the wellbore 10. The sensors 42 may include, accelerometers,
35 inclinometers, magnetometers, and navigational devices. The drilling assembly
further includes a variety of sensors denoted herein by numeral 43 for providing
40 information about the borehole parameters, drilling parameters and drilling
20 assembly condition parameters, such as pressure, temperature, fluid flow rate,
differential pressure across the mud motor, equivalent circulatory density of the

5 drilling fluid, drill bit and/or mud motor rotational speed, vibration, weight on bit, etc.
Formation evaluation sensors 40 (also referred to as the "FE" sensors) are included
10 in the drilling assembly 30 to determine properties of the formations 77 surrounding
the wellbore 10. The FE sensors typically include resistivity, acoustic, nuclear and
5 nuclear magnetic resonance sensors which alone provided measurements that are
used alone or in combination of measurements from other sensors to calculate,
15 among other things, formation resistivity, water saturation, dielectric constant,
porosity, permeability, pressure, density, and other properties or characteristics of
20 the formation 77. A two-way telemetry unit 44 communicates data/signals between
10 the drilling assembly 30 and a surface control unit or processor 70, which usually
includes a computer and associated equipment.

25
During drilling, according to one aspect of the present invention, flowable
30 devices 63 are introduced at one or more suitable locations into the flow of the
drilling fluid 60. The flowable devices 63 travel with the fluid 60 down to the BHA
15 30 (forward flow), wherein they are channeled into a passage 69. A data exchange
device 72, usually a read/write device disposed adjacent to or in the passage 69,
35 which can read information stored in the devices 63 (at the surface or obtained
during flow) and can write on the devices 63 any information that needs to be sent
40 back to the surface 11. An inductive coupling unit or another suitable device may
20 be used as a read/write device 72. Each flowable device 63 may be programmed

5 at the surface with a unique address and specific or predetermined information.
Such information may include instructions for the controller 73 or other electronic
10 circuits to perform a selected function, such as activate ribs 74 of a force application
unit to change drilling direction or the information may include signals for the
5 controller 73 to transmit values of certain downhole measured parameters or take
15 another action. The controller 73 may include a microprocessor-based circuit that
causes the read/write unit 72 to exchange appropriate information with the flowable
20 devices 63. The controller 73 process downhole the information received from the
flowable devices 63 and also provides information to the devices 63 that is to be
10 carried to the surface. The read/write device 72 may write data that has been
gathered downhole on the flowable devices 63 leaving the passage 69. The
25 devices 63 may also be measurement or sensing devices, in that, they may provide
measurements of certain parameters of interest such as pressure, temperature, flow
30 rate, viscosity, composition of the fluid, presence of a particular chemical, water
saturation, composition, corrosion, vibration, etc. The devices 63 return to the
15 surface 11 with the fluid circulating through the annulus 13 between the wellbore 10
and drill string 22.

40 The flowable devices returning to the surface designated herein for
20 convenience by numeral 63a are received at the surface by a recovery unit 64. The
returning devices 63a may be recovered by filtering magnetic force or other

5 techniques. The information contained in the returning devices 63a is retrieved,
interpreted and used as appropriate. Thus, in the drilling mode, the flowable
10 devices 63 flow downhole where they perform an intended function, which may be
taking measurements of a parameter of interest or providing information to a
5 downhole controller 73 or retrieving information from a downhole device. The
15 devices 63a return to the surface (the return destination) via the annulus 13.

During drilling, some of the devices may be lost in the flow process or get
20 attached or stuck to the wall of the wellbore 10. Redundant devices may be
10 supplied to account for such loss. Once the controller 73 has communicated with
a device having a particular address, it may be programmed to ignore the redundant
25 device. Alternatively, the controller 73 may cause a signal to be sent to the surface
confirming receipt of each address. If a particular address is not received by the
30 downhole device 72, a duplicate device may be sent. The devices 63a that get
15 attached to the wellbore wall 10a (see Figure 2), may act as sensors or
communication locations in the wellbore 10. A stuck device may communicate with
35 another flowable device stuck along the wall 10a or with devices passing adjacent
the stuck device, thereby forming a communications network. The returning devices
63a can retrieve information from the devices stuck in the well 10. Thus, the
40 20 flowable devices in one aspect, may form a virtual network of devices which can
pass data/information to the surface. Alternatively, some of the devices 63 may be

5 adapted or designed to lodge against or deposited on the wellbore wall 10a, thereby
providing permanent sensors and/or communication devices in the wellbore 10. In
10 one embodiment, the flowable devices may be designed to be deposited on the
borehole wall during the drilling process. As one flowable device can communicate
5 with another neighboring flowable device, a plurality of flowable devices deposited
on the wellbore wall may form a communications network. As drilling of new
15 formation continues new flowable devices are constantly deposited on the borehole
wall to maintain the network. When drilling of the section is completed, the flowable
20 devices may be retrieved from the borehole wall for use in another application. The
10 devices 63 may include a movable element that can generate power due to
turbulence in the wellbore fluid, which power can be used to change a resident
25 battery in the flowable devices. Further, the devices 63 may include a propulsion
mechanism (as more fully explained in reference to Figure 6) that aids these
30 devices in flowing with or in the fluid 60. The devices 63 usually are autonomous
15 devices and may include a dynamic ballast that can aid such devices to flow in the
fluid 60.

35
Flowable devices may also be periodically planted in the wellbore wall in a
controlled operation to form a communication line along the wellbore, as opposed
40 20 to randomly depositing flowable devices using the hydraulic pressure of the drilling
fluid. An apparatus may be constructed as part of the downhole assembly to
45 mechanically apply a force to press or screw the flowable device into the wellbore

5 wall. In this operation, the force required to implant the device may be measured,
either by sensors within the flowable device itself or sensors within the implanting
apparatus. This measured parameter may be communicated to the surface and
10 used to investigate and monitor rock mechanical properties. The flowable devices
5 may be pumped downhole to the planting apparatus, or kept in a magazine
downhole to be used by the planting apparatus. In this case the flowable devices
15 may be permanently installed. Figure 2 which is a schematic illustration of a
wellbore, wherein devices made in accordance with the present invention are
implanted in the borehole wall during drilling of the wellbore 10 to form a
20 communication network. Figure 2 shows a well 10 being drilled by drill bit 26 at the
bottom of a drilling assembly 80 carried by a drilling tubing 81. Drilling fluid 83
25 supplied under pressure through the tubing 81 discharges at the bottom of the drill
bit 26. Flowable devices 63 are introduced or pumped into the fluid 83 and captured
or retrieved by a device 84 in the drilling assembly 80. The drilling assembly 80
30 includes an implanting device 85 that implants the retrieved flowable devices 63 via
a head 86 into the borehole wall 10a. The devices which are implanted during the
drilling of the wellbore 10 are denoted by numeral 63b. The devices 63 may be
35 pumped downhole through a dedicated tubing 71 placed in the drilling tubing 81.
If coiled tubing is used as the tubing 81, the tubing 71 for carrying the flowable
40 devices 63 to the implanter 85 may be built inside or outside the coiled tubing.

5 Alternatively, the devices to be implanted may be stored in a chamber or
magazine 83, which deliver them to the implanter 85. The implanted flowable
10 devices 63b in the well 10 can exchange data with each other and/or other flowable
devices returning to the surface via the annulus 13 and/or with other devices in the
5 drill string as described above in reference to Figure 1. A communication device
15 88 may be disposed in the well at any suitable location, such as below the upper
casing 12 to communicate with the implanted devices 63b. The communication
device 88 may communicate with one or more nearby flowable devices 63b such
20 as a device denoted by numeral 63b, which device then communicates with next
10 device and so forth down the line to the remaining implanted devices 63b. Similarly,
the implanted devices 63b communicate uphole up to the devices 63b which
25 communicates with the device 88, thus establishing a two-way communication link
or line along the wellbore 10. The device 88 can read data from and write data on
30 the devices 63b. It is operatively coupled to a receiver/transmitter unit 87 and a
15 processor 89 at the surface by a conductor or link 91. The link 91 may be an
electrical conduct or a fiber optic link. The processor 89 processes the data
35 received by the receiver/transmitter unit 87 from the devices 63b and also sends
data to the devices 63b via the receiver/transmitter 87. The implanted devices 63b
40 may be used to take measurements for one or more selected downhole parameters
20 during and after the drilling of the wellbore 10.

5 **Figure 3** illustrates an alternative method of transporting the devices **63** to
a downhole location. **Figure 3** shows a wellbore **101** formed to a depth **102**. For
simplicity and ease of understanding, normal equipment and sensors placed in a
10 wellbore are not shown. A fluid conduit **110** is disposed in the wellbore. The
5 conduit **110** runs from a fluid supply unit **112**, forms a U-return **111** and returns to
the surface **11**. Flowable devices **63** are pumped into the conduit **110** by the supply
15 unit **112** with a suitable fluid. A downhole device **72a** retrieves information from the
flowable devices **63** passing through a channel **70a** and/or writes information on
20 such devices. A controller **73a** receives the information from the flowable devices
10 **63** and utilizes it for the intended purpose. Controller **73a** also controls the
operation of the device **72a** and thus can cause it to transfer the required
25 information onto the flowable devices **63**. The flowable devices **63** then return to
the surface via the return segment **110a** of the tubing **110**. A retrieval unit **120** at
30 the surface recovers the returning flowable devices **63a**, which may be analyzed by
15 a controller **122** or by another method. The devices **63** may perform sensory and
other functions described above in references to **Figure 1**.

35 **Figure 4** is a schematic illustration of a production well **200** wherein flowable
devices **209** are released into the produced fluid or formation fluid **204**, which
40 carries these devices to the surface. **Figure 4** shows a well **201** that has an upper
20 casing **203** and a well casing **202** installed therein. Formation fluid **204** flows into
45

5 the well 201 through perforations 207. The fluid 204 enters the wellbore and flows
to the surface via a production tubing 210. For simplicity and ease of
10 understanding, Figure 4 does not show the various production devices, such as
flow control screens, valves and submersible pumps, etc. A plurality of flowable
5 devices 209 are stored or disposed in a suitable container at a selected location 211
in the wellbore 201. The devices 209 are selectively released into the flow of the
15 produced fluid 204, which fluid carries these devices, the released devices are
designated by numeral 209a to the surface. The devices 209a are retrieved by a
20 retrieval unit 220 and analyzed. As noted above in reference to Figures 1 and 3,
10 the flowable devices 209a may be sensor devices or information containing devices
or both. Periodic release of sensory devices can provide information about the
25 downhole conditions. Thus, in this aspect of the invention, the flowable devices are
released in the well 201 to transfer downhole information during the production
30 phase of the well 201.

15
Communication in open-hole sections may be achieved using flowable
35 devices in the drilling mud deposited on the borehole wall, or by using implanted
flowable devices as described above. In cased hole sections often found above
open-hole sections, communications may be achieved in several ways; through
40 20 flowable devices deposited in the mud filter cake or implanted in the borehole wall
during the drilling process, or through flowable devices mixed in the cement which

5 fills the annulus between the borehole wall/mud filter cake and the casing, or
through a communication channel installed as part of the casing. The latter may
include a receiver at the bottom of the casing to pick up information from the
10 devices, and a transmitter to send this information to the surface and vice versa.

5 The communication device associated with the casing could be an electrical or fibre-
optic or other type of cable, an acoustic signal or an electromagnetic signal carried
15 within the casing or within the earth, or other methods of communication. In
conclusion, a communication system based on the use of flowable devices may be
20 used in combination with other communication methods to cover different sections
10 of the wellbore, or to communicate over distances not covered by a wellbore.

25 Another example of using flowable devices in combination with other
communication systems is a multilateral well. One or more laterals of the well may
have a two-way communication system with flowable devices, while one or more
30 15 laterals of the same well may not have a full two-way communication system with
the flowable devices. In one embodiment of the invention, the first lateral is
equipped with a single tube or a U-tube that allows flowable devices containing
35 information from surface to travel to the bottom of the first lateral. The second
lateral is not equipped with a tubing, but has flowable devices stored in a downhole
40 20 magazine. A message to the second lateral is pumped into the first lateral. From
the receiver station in the first lateral, information such as a command to release a
flowable device in the second lateral, is transmitted from the first lateral to the
45

5 second lateral through acoustic or electromagnetic signals through the earth. Upon
receipt of this information in the second lateral, the required task, such as writing to
10 and releasing a flowable device or initiating some action downhole is performed.
Provided the distance and formation characteristics allow transmission of signal
5 through the earth formation, the same concept can be used to communicate
15 between individual wellbores.

Figure 5 is an exemplary schematic illustration of an multilateral production
20 well 300, wherein flowable devices are pumped into one branch or lateral and then
10 utilized for communication between the laterals. Figure 5 shows a main well
section 301 having two branch wells or laterals 301a and 301b. In the exemplary
25 lateral wellbore configuration of Figure 5, both wells 301a and 301b are shown to
be production wells. Well 301a and 301b produce fluids (hydrocarbons) which are
shown by arrow 302a and 302b, respectively. Flowable devices 63 are pumped into
30 the first lateral 301a via a tubing 310 from a supply unit 321 at the surface 11. The
15 devices 63 are discharged at a known depth 303a where a receiver unit 370a
retrieves data from the devices 63. The devices return to the surface with the
35 produced fluid 302a. The returning devices from wellbore 301 are denoted by 63d.
A transmitter unit 380 transmits signals 371 in response to information retrieved
40 from the flowable devices 63. A second receiver 370b in the second lateral 301b
20 receives signals 371. A controller unit or processor 382 utilizes the received signals
45

5 to perform an intended function or operation, which may include operating a device
downhole, such as a valve, a sliding sleeve, or a pump, etc. Flowable devices 63c
10 may be disposed in magazine 383 in the second lateral 301b and released into the
fluid flow 302b by the controller 382. The devices 63d and 63c flowing uphole are
5 retrieved at the surface by a receiver unit 320 and the data carried by the flowable
15 devices 63c and 63d is processed by the processor 322. It should be noted that
Figure 5 is only one example of utilizing the flowable devices in multiple wellbores.
The wells selected for intercommunication may be separate wells in a field. The
20 signals 371 may be received by instruments in one or more wells and/or at the
10 surface for use in performing an intended task.

25 Figure 6 shows a block functional diagram of a flowable device 450
according to one embodiment of the present invention. The device 450 is preferably
encapsulated in a material 452 that is suitable for downhole environment such as
30 ceramic, and includes one or more sensor elements 454, a control circuit or
15 controller 456 and a memory unit 458. A resident power supply 450 supplies power
to the sensor 454, controller 456, memory 458 and any other electrical component
35 of the device 450. The controller 456 may include a processor that interacts with
one or more programs in the device to process the data gathered by the device
40 and/or the measurements made by the device to compute, at least partly, one or
20 more parameters of interest, including results or answers. For example, the device

5 450 may calculate a parameter, change its future function and/or transmit a signal
in response to the calculated parameter to cause an action by another flowable
10 device or a device in the wellbore. For example, the device may determine a
detrimental condition downhole, such as presence of water and then send a signal
5 to a fluid flow control device in the wellbore to shut down a production zone or the
well. The device may be designed to have sufficient intelligence and processing
15 capability so it can take any number of different actions in the wellbore. A power
generation unit that generates electrical power due to the turbulence in the flow may
20 be incorporated in the device 450 to charge a battery (resident power supply) 460.
10 An antenna 462 is provided to transmit and/or receive signals, thereby providing
one-way or two-way communication (as desired) between the flowable device 450
25 and another device, which may be a flowable device or a device located downhole
or at the surface. The device 450 may be programmed at the surface or downhole
30 to carry data and instructions. The surface information programmed into a flowable
15 device is read by a device in the wellbore while the downhole programmed
information may be read at the surface or by reading devices downhole. The device
35 450 may transmit and receive signals in the wellbore and thus communicate with
other devices. Such a flowable device can transfer or exchange information with
40 other devices, establish communication link along the wellbore, provide two-way
20 communication between surface and downhole devices, or between different
wellbores in a field or laterals of a wellbore system, and establish a communication
45 network in the wellbore and/or between the surface instrumentation and downhole

5 devices. Each such device may be coded with an identification number or address,
which can be utilized to confirm the receipt or transfer of information by the devices
deployed to receive the information from the flowable device 450. In one method,
10 the flowable device 450 may be sequentially numbered and introduced into the fluid
flow to be received at a target location. If the receiving device receives a flowable
5 device, it can cause a signal to be sent to the sending location, thereby confirming
the arrival of a particular device. If the receiving device does not confirm the arrival
15 of a particular device, a second device carrying the same information and the
address may be sent. This system will provide a closed loop system for transferring
20 information between locations.
10

25 In another aspect of the invention, the flowable device may contain a
chemical that alters a state in response to a downhole parameter, which provides
a measure of a downhole parameter. Other devices, such as devices that contain
30 biological mass or mechanical devices that are designed to carry information or
sense a parameters may also be utilized. In yet another aspect, the flowable device
15 may be a device carrying power, which may be received by the receiving device.
Thus, specially designed flowable devices may be utilized to transfer power from
35 one location to another, such as from the surface to a downhole device.
20

40 The flowable device 450 may include a ballast 470 that can be released or
activated to alter the buoyancy of the device 450. Any other method also may be
45

5 utilized to make the device with variable buoyancy. Additionally, the device 450
may also include a propulsion mechanism 480 that can be selectively activated to
10 aid the device 450 to flow within the fluid path. The propulsion mechanism may be
self-activated or activated by an event such as the location of the device 450 in the
5 fluid or its speed.

15 While the foregoing disclosure is directed to the preferred embodiments of
the invention, various modifications will be apparent to those skilled in the art. It is
20 intended that all variations within the scope and spirit of the appended claims be
10 embraced by the foregoing disclosure.

Claims

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WHAT IS CLAIMED IS:

1. A method of utilizing discrete devices in a wellbore wherein a working fluid provides fluid flow path for moving said discrete devices from a first location of introduction of said devices into the flow path to a second location of interest, said method comprising:

- selecting at least one flowable discrete device constituting a data carrier that is adapted to be moved in the wellbore at least in part by the working fluid ("flowable device");
- introducing the at least one flowable discrete device into the fluid flow path at the first location to cause the working fluid to move the at least one flowable device to the second location of interest; and
- providing a data exchange device in the fluid flow path for effecting data exchange with the at least one flowable discrete device.

2. The method of claim 1, wherein selecting the at least one flowable device comprises selecting the at least one flowable device from a group consisting of: (i) a device having a sensor for providing a measure of a parameter of interest; (ii) a device having a memory for storing data therein; (iii) a device carrying energy that is transmittable to another device; (iv) a solid mass carrying a chemical that alters a state when said solid mass encounters a particular property in the wellbore; (v) a

5 7 device carrying a biological mass; (vi) a data recording device; (vii) a device that is
8 adapted to take a mechanical action, and (viii) a self-charging device due to
9 interaction with the working fluid in the wellbore.

10
11 1 3. The method of claim 1, wherein said selecting the at least one flowable
12 device comprises selecting a device that provides a measure of a parameter of
13 interest selected from a group consisting of: (i) pressure; (ii) temperature; (iii) flow
14 rate; (iv) vibration; (v) presence of a particular chemical in the wellbore; (vi)
15 viscosity; (vii) water saturation; (viii) composition of a material; (ix) corrosion; (x)
16 velocity; (xi) a physical dimension; and (xi) deposition of a particular matter in a fluid.

17 1 4. The method of claim 1, wherein selecting at least one flowable device
18 comprises selecting a device that comprises:

- 19 3 - a sensor for providing a measurement representative of a parameter
20 4 of interest;
21 5 - a memory for storing data relating at least in part to the parameter of
22 6 interest;
23 7 - a source of power for supplying power to a component of said
24 8 flowable device; and
25 9 - a controller for determining data to be carried by said memory.

5
1 5. The method according to claim 4 further comprising providing a transmitter
2 for the at least one flowable device for effecting data exchange with the flowable
3 device.
10

1 6. The method of claim 5, wherein effecting the data exchange comprises
2 communicating with said at least one flowable device by a method selected from a
3 group consisting of: (i) electromagnetic radiation; (ii) optical signals; and (iii) acoustic
4 signals.
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1 7. The method of claim 1, wherein selecting the at least one flowable device
2 comprises selecting a flowable device that is adapted to carry data that is one of (i)
3 prerecorded on the at least one flowable device; (ii) recorded on the at least one
4 flowable device downhole; (iii) self recorded by the at least one flowable device; (iv)
5 inferred by a change of a state associated with the at least one flowable device.
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1 8. The method of claim 1, wherein selecting the at least one flowable comprises
2 selecting a device from a group of devices consisting of: (i) a device that is freely
3 movable by the working fluid; (ii) a device that has variable buoyancy; (iii) a device
4 that includes a propulsion mechanism that aids the at least one flowable device to
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5 flow within the working fluid; (iv) a device that is movable within by a superimposed
6 field; and (v) a device whose movement in the working fluid is aided by the
7 gravitational field.

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1 9. The method of claim 1, wherein selecting the at least one flowable device
2 comprises selecting a device that is one of: (i) resistant to wellbore temperatures;
15 3 (ii) resistant to chemicals; (iii) resistant to pressures in wellbores; (iv) vibration
4 resistant; (v) impact resistant; (vi) resistant to electromagnetic radiation; (vii)
20 5 resistant to electrical noise; and (viii) resistant to nuclear fields.

25 1 10. The method of claim 1, wherein said introducing the at least one flowable
2 device into the working fluid further comprises delivering the at least one flowable
3 device to the working fluid by one of (i) an isolated flow path; (ii) a chemical injection
4 line; (iii) a tubing in a wellbore; (iv) a hydraulic line reaching the second location of
30 5 interest and returning to the surface; (v) through a drill string carrying drilling fluid;
6 (vi) through an annulus between a drill string and the wellbore; (vii) through a tubing
35 7 disposed outside a drill string; and (viii) in a container that is adapted to release said
8 at least one flowable device in the wellbore.

40 1 11. The method of claim 1 further comprising recovering said at least one
2 flowable device.

5 1 12. The method of claim 14, wherein recovering the at least one flowable device
2 2 comprises recovering the at least one flowable device by one of (i) fluid to solid
3 3 separation; and (ii) fluid to fluid separation.

10 1 13. The method of claim 1, wherein said introducing the at least one flowable
15 2 device includes introducing a plurality of flowable devices each such flowable device
3 3 adapted to perform at least one task.

20 1 14. The method of claim 13, wherein said introducing a plurality of flowable
2 2 devices comprises one of (i) timed release; (ii) time independent release; (iii) on
3 3 demand release; and (iv) event initiated release.

25 1 15. The method of claim 1, wherein introducing said at least one flowable device
30 2 comprises delivering a plurality of flowable devices into fluid circulating in a wellbore
3 3 to cause at least a number of the flowable devices to remain in the wellbore at any
4 4 given time, thereby forming a network of the flowable devices in the wellbore.

35 1 16. The method of claim 15, wherein the flowable devices in said plurality of
40 2 devices are adapted to communicate information with other devices, thereby
3 3 forming communication network in the wellbore.

5

1 17. The method of claim 1 further comprising providing a unique address to the
2 at least one flowable device.

10

1 18. The method of claim 1 further comprising providing a data communication
2 device in the wellbore for communicating with the at least one flowable device.

15

1 19. The method of claim 18 further comprising causing the data communication
2 to exchange data with the at least one flowable device and to transmit a signal
3 confirming said data exchange.

20

1 20. The method of claim 1, wherein said selecting said at least one flowable
2 device comprises selecting the at least one flowable device that includes a sensor
3 that is one of (i) mechanical (ii) electrical; (iii) chemical; (iv) nuclear; and (v)
4 biological.

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1 21. The method of claim 1 further comprising implanting a plurality of spaced
2 apart flowable devices in said wellbore during drilling of said wellbore.

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1 22. The method of claim 7 further comprising receiving the data carried by said
2 at least one flowable device by a downhole device and transmitting a signal in
3 response to said received signal to a device located outside said wellbore.

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1 23. The method according to claim 22 further comprising said device outside said
2 wellbore at a location that is one of: (i) in a lateral wellbore associated with said
3 wellbore; (ii) a separate wellbore; (iii) at the surface; and (iv) in an injection well.
10

1 24. A wellbore system utilizing at least one flowable device constituting a data
15 2 carrier that is adapted to be moved by a fluid flowing in the wellbore comprising:

3 (a) a forward fluid flow path associated with the wellbore for moving the
4 at least one flowable device from a first location of introduction of the
20 5 at least one flowable device into the forward fluid path to a second
6 location of interest;

7 (b) a data exchange device at the second location of interest for effecting
25 8 data exchange with the at least one flowable device that is one of (i)
9 retrieving information carried by the at least one flowable device; or
30 10 (ii) inducing selected information on the at least one flowable device.

1 25. The wellbore system of claim 24 further comprising a return fluid flow path
35 2 for moving the at least one flowable device from the second location of interest to
3 a return destination.

40 1 26. The wellbore system of claim 24, wherein the first location of introduction and
2 the return destination are at the surface.

5
1 27. The wellbore system of claim 25, wherein the forward flow path is through a
2 drill string utilized for drilling the wellbore and the return fluid flow path is an annulus
3 between the drill string and the wellbore.
10

1 28. The wellbore system of claim 25, wherein (i) the forward fluid flow path
15 2 comprises a first section of a u-tube extending from the first location to the second
3 location of interest and (ii) the return path comprises a second section of the u-tube
4 returning to the return destination.
20

1 29. The wellbore system of claim 24, wherein the second location of interest is
2 in the wellbore and the data exchange device is located proximate said second
25 3 location of interest.

30 1 30. The wellbore system of claim 24 further comprising a controller for
2 performing an operation that is one of (i) retrieving information from the at least one
3 flowable device from the data exchange device, or (ii) causing the data exchange
35 4 devices to induce a particular information onto the at least one flowable device.

40 1 31. The wellbore system of claim 25 further comprising a control unit for
2 processing data contained in the flowable device returning to the destination.
45

5 1 32. The wellbore system of claim 30, wherein the controller performs at least one
2 operation in response to the data retrieval from the at least one flowable device.

10 1 33. A system for implanting at least one flowable device in the wall of the
2 wellbore during drilling of the wellbore, comprising:

- 15 3 - a drill string having a drill bit at end thereof for drilling the wellbore;
4 - a source of drilling fluid for supplying the drilling fluid to the drill string;
5 - a source for introducing at least one flowable device into the drilling
20 6 fluid; and
7 - an implanting device carried by the drill string uphole of the drill bit,
8 said implanting device receiving the at least one flowable device from
25 9 the drilling fluid and implanting the at least one flowable device in the
10 wall of the wellbore.

30 1 34. A method of utilizing flowable devices in a wellbore carrying a fluid from a
2 downhole location to the surface, each flowable device constituting a data carrier
35 3 and adapted to be moved by the fluid, said method comprising:

- 4 - locating a plurality of flowable devices at a selected location in a
5 wellbore; and
40 6 - selectively releasing the flowable devices into fluid, thereby moving
7 the flowable devices carry data from the selected location in the
8 wellbore to the surface.

5

9 35. The method of claim 34, wherein the locating of a plurality of the flowable
10 devices includes locating said devices in a magazine from where said devices are
11 individually releaseable into the flow of the fluid.

10

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1 36. The method of claim 34 further comprising providing a controller in the
2 wellbore for inducing information n to the at flowable devices prior to their release
3 into the fluid.

20

1 37. The method of claim 34, wherein the releasing the flowable devices includes
2 at least one of (i) releasing the flowable devices at predetermined time intervals, (ii)
3 releasing a flowable device upon the occurrence of a particular event; or (iii)
4 releasing the flowable devices periodically.

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1 38. A discrete flowable device adapted to be moved at least partially by a fluid
2 flowing in a wellbore, comprising:

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- 3 - a sensor for taking measurements relating to a wellbore parameter;
- 4 - a controller for processing the sensor measurements;
- 5 - a memory for storing data;
- 6 - a power source for supplying power to elements of the flowable
40 device;
- 7 - an antenna for communicating information to a device external to the
8 flowable device; and
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5 10 a body housing the sensor, controller, memory and the power source,
 11 which body is adapted to protect the device from wellbore conditions.

10 1 39. The discrete flowable device according to claim 38 further comprising an
 2 external member that interacts with fluid in the wellbore to aid in generating
15 3 electrical energy.

 1 40. The discrete flowable device according to claim 39, wherein the electrical
20 2 energy is utilized to charge the power supply.

 1 41. The discrete flowable device according to claim 38 further comprising a
25 2 buoyancy device to alter the buoyancy of the discrete flowable device.

30 1 42. The discrete flowable device according to claim 38 further comprising a
 2 propeller for aiding the discrete flowable device to flow in the wellbore.

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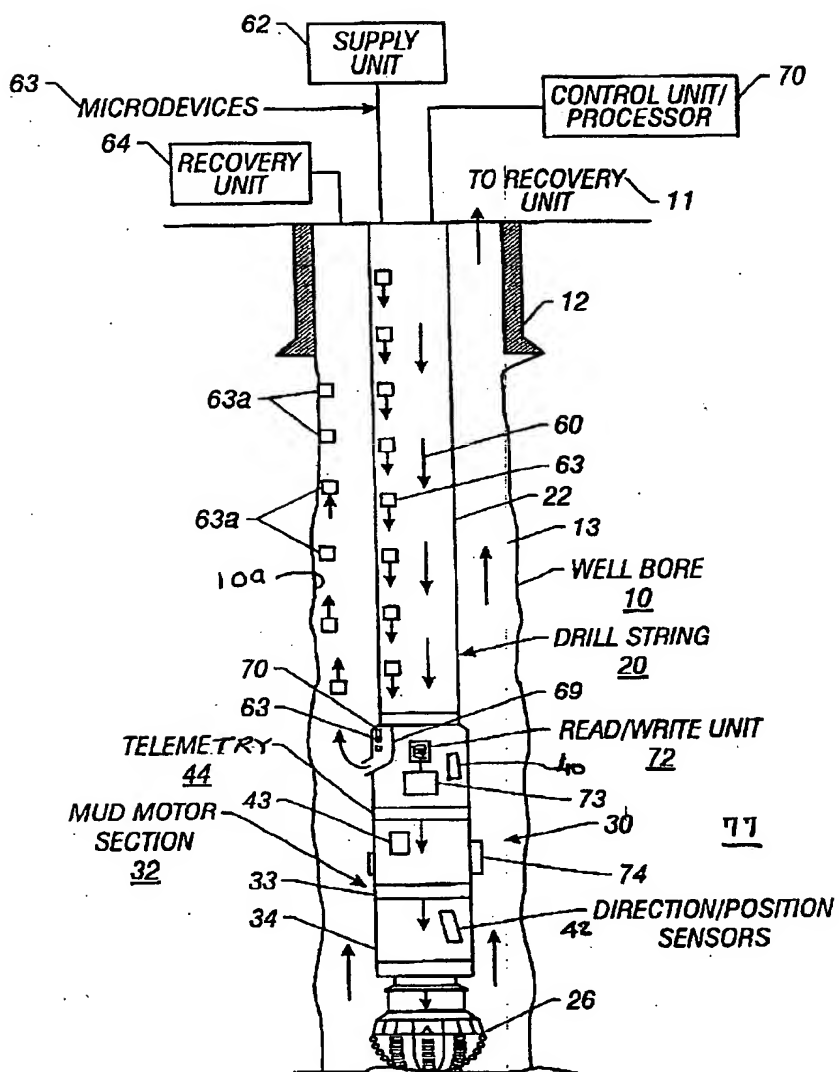
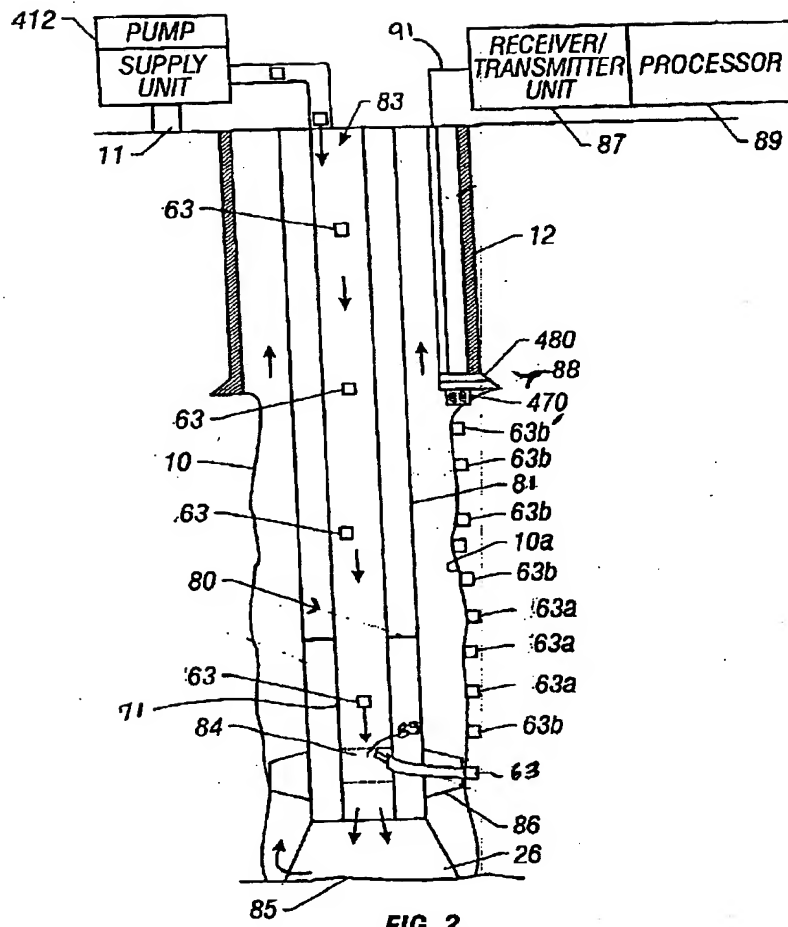


FIG. 1

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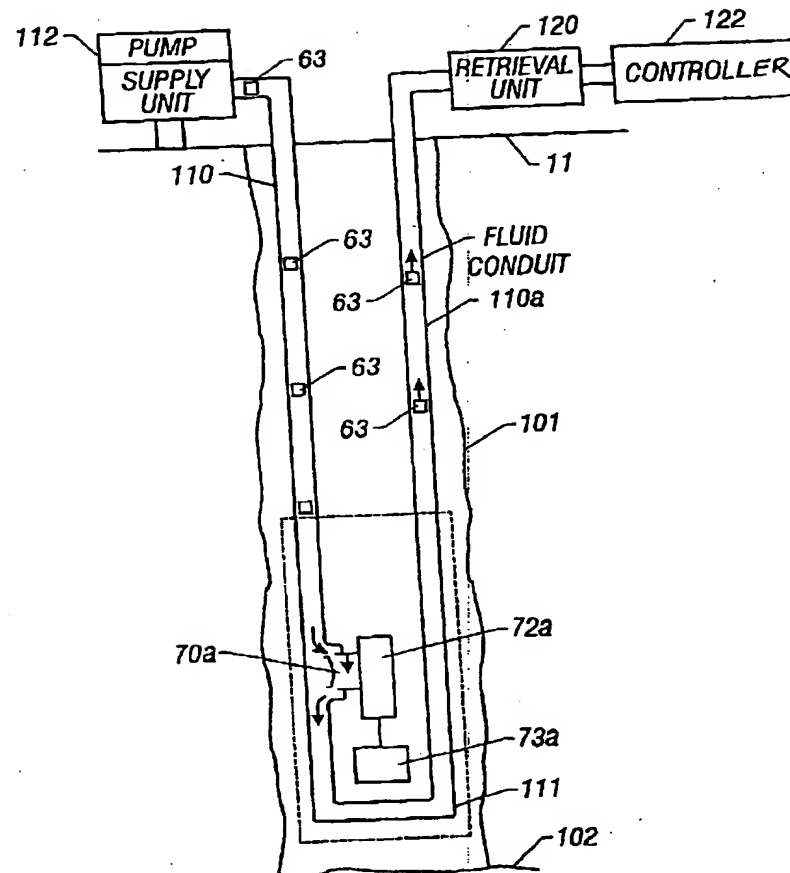


FIG. 3

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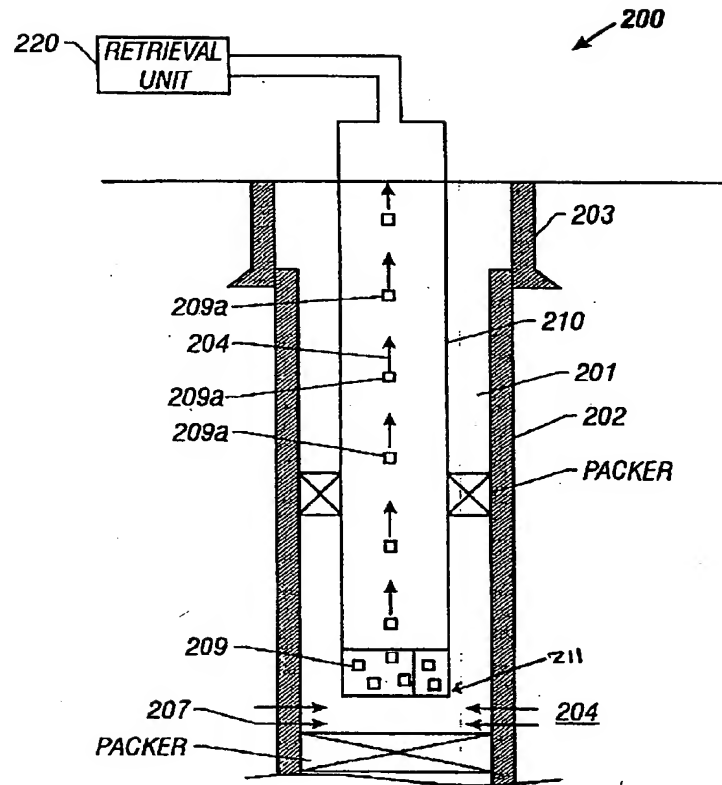


FIG. 4

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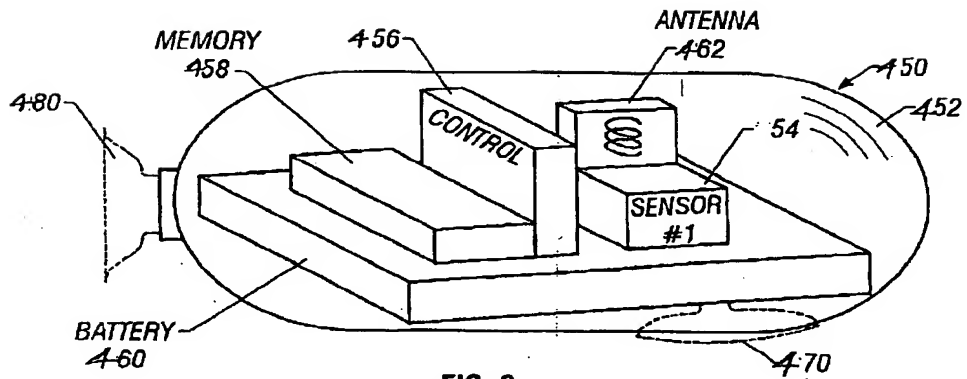


FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 00/14464

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 E21B47/01 E21B47/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 NV Rijswijk
 Tel. (+31-70) 340-2040, Tx. 31 851 epo nl,
 Fax: (+31-70) 340-3016

Authorized officer

Garrido Garcia, M

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information on patent family members

Intern. Application No

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